AD NUMBER
ADB001032
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; NOV 1973. Other requests shall be referred to Office of the Director (Defense Research and Engineering), Washington, DC 20301. This document contains export-controlled technical data.**
AUTHORITY
ODDR ltr, 24 Oct 1975

AD B001032

UNCLASSIFIED

Copy 8 of 104 copies

SECOND ADDENDUM

WSEG REPORT 197

DESIGN OF A FIELD TEST FOR PROBABILITY OF HIT BY ANTIAIRCRAFT GUNS

November 1973

DDC
RECEIVED
JAN 12 1975
C

Including
IDA PAPER P-921

J. R. Transue, *Project Leader*

INSTITUTE FOR DEFENSE ANALYSES
SYSTEMS EVALUATION DIVISION

WEAPONS SYSTEMS EVALUATION GROUP
400 ARMY-NAVY DRIVE, ARLINGTON, VA.

UNCLASSIFIED

Log. No. 165887

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Director of Defense Research and Engineering, Washington, D.C. 20301.

~~Each transmittal of this document outside the Department of Defense must have prior approval of the Director of Defense Research and Engineering, Washington, D. C. 20301.~~

Further reproduction of this document is prohibited without prior approval of the Director of Defense Research and Engineering, Washington, D.C. 20301.

UNCLASSIFIED

SECOND ADDENDUM,

PAPER P-921-Add-2

DESIGN OF A FIELD TEST FOR PROBABILITY OF HIT BY ANTIAIRCRAFT GUNS.

J. R. Transue, *Project Leader*

G. L. Brown
C. T. Ireland

WSEG, IDA/HQ

197-Add-2, 73-15642

November 1973

24 p.

This report has been prepared by the Systems Evaluation Division of the Institute for Defense Analyses in response to the Weapons Systems Evaluation Group Task Order DAHC 15-73-C-0200/T-182, revised 18 September 1972.

In the work under this Task Order, the Institute has been supported by military personnel assigned by WSEG.

Distribution limited to U.S. Gov't. agencies only; Test and Evaluation; Nov 73. Other requests for this document must be referred to DDR&E

INSTITUTE FOR DEFENSE ANALYSES
SYSTEMS EVALUATION DIVISION
400 Army-Navy Drive, Arlington, Virginia 22202

UNCLASSIFIED

IDA Log No. HQ 73-15642

403307 DN

CONTENTS

PREFACE

This is the second addendum to the test design for HITVAL, "Design of a Field Test for Probability of Hit by Antiaircraft Guns," WSEG Report 197. The first addendum was necessitated by changes in the flight paths planned for the fixed-wing aircraft. The present addendum results from the elimination of crew fatigue from the test design, and from a desire to structure the test so that analysis will still be possible if only half (the first half or the second half) of the first two experimental designs are conducted. Since planning for the test is not yet complete, further changes to the test (and hence additional addenda to the test design report) are still possible.

Chapter I

INTRODUCTION

WSEG/IDA/DDR&E and the HITVAL Joint Service Test Director have agreed upon a number of experimental changes which require changes in the test design as presented in Chapter II of WSEG Report 197 (IDA Paper P-921), Design of a Field Test for Probability of Hit by Antiaircraft Guns, February 1973.

Some of these changes were noted and appropriately revised designs were presented in the Addendum to WSEG Report 197. Since that addendum does not include all the changes which have been made, and since all parts of the experimental design are now affected by the changes, it appears worthwhile to produce a revised version of Chapter II of WSEG Report 197.

The previous addendum discussed experimental changes related to the fixed-wing, single aircraft, firing experiment which eliminated *offset* and *breakaway acceleration* as factors, increased the value of one level of the *speed* factor and replaced the *exit maneuver* factor by an *exit direction* factor which contains the *factor offset*.

The experimental changes which have been agreed upon since the publication of the addendum are:

- The reduction in the number of crews for each gun from four to two.
- The decision that the *fatigue* factor cannot be implemented effectively and the replacement of this factor by a guncrew *time* (or learning) factor.
- The allowance for the possibility that some guns may not be operable throughout the complete experiment; the design is altered so as to permit analysis of variance procedures to be applied formally to the first eight days of experimentation (one-half the total experiments described in Tables 1 and 2).

Chapter II of this paper is presented in the same format as Chapter II of WSEG Report 197 and supersedes that chapter and the addendum as a description of the test design.

Chapter II

TEST CONDITIONS

This chapter presents the objectives of the experimental design and describes the factors and levels included in the design. It then presents the design in a tabular form that shows the order of testing as well as the combinations of factor levels for each trial.

The experimental design is simply a description of the test conditions of each trial of an experiment. The test conditions are described by specifying the level (value) of each factor (controlled variable). For example, in part of the present design, one of the factors is the dive angle of the fixed-wing aerial target. This factor has two levels--15 degrees and 45 degrees.

A. OBJECTIVES OF THE EXPERIMENTAL DESIGN

There are two objectives of carefully selecting the set of test conditions making up the experimental design. The first objective is to permit the use of particular methods of mathematical statistics to determine the influence of the factors on the observations (the values of observed variables). Thus, if the dive angle of aerial targets affects the angular tracking accuracy of an antiaircraft gun, a statistical test for this main effect (the effect of a single factor) would likely be significant (would indicate that there is an effect). If the experiment were conducted repeatedly, the fraction of times that the statistical test would be significant would depend on the magnitude of the effect and on the number of trials in each

experiment, the fraction being greater for larger effects and for larger numbers of trials.

The second objective is to ensure that the experiment covers the wide spectrum of conditions for which the models (the mathematical models of antiaircraft guns firing at aircraft) are intended and for which the models should be validated. For example, the breakaway distances and speeds used in the tests with fixed-wing aircraft provide a spectrum of angular tracking rates and accelerations at the gun.

B. FACTORS AND LEVELS OF THE EXPERIMENTAL DESIGN

The experimental design for the HITVAL test consists of several parts each of which is itself an experimental design. That is, there are fixed-wing and rotary-wing parts, firing and nonfiring parts, etc. The parts are so designed that particular pairs can be combined to form a larger design. This will be clarified now by considering the tabulated design.

Each of Tables 1, 2, and 3 lists the factors and levels for a part of the design. The symbols listed in these tables are used in later tables to concisely give the test conditions. In Tables 1, 2, and 3 the factor *crew* refers to the crew of an antiaircraft gun. There are two crews for each gun. The factor *crew* exists at two levels--designated by the symbols C_1 and C_2. Note that *level* does not imply skill level.

It is believed that the performance of the guncrew can make a great difference in the effectiveness of antiaircraft guns, particularly guns that rely on manual tracking or other manual functions. Unfortunately, there is presently no way to determine in advance how well individuals will perform as members of a guncrew.

The crews should be so composed that all crews labeled "Crew 1" share certain characteristics, and similarly for the crews with the other label. Then if these characteristics

Table 1. FACTORS AND LEVELS--FIXED WING SINGLE AIRCRAFT, FIRING

Factor	Level 1	Level 2	Level 3	Level 4
Crew	C_1, Crew 1	C_2, Crew 2	--	--
Time	T_1, First half	T_2, Last half	--	--
Dive Angle	D_1, 15°	D_2, 45°	--	--
Breakaway Distance[a]	B_1, 1.5 km	B_2, 3 km	--	--
Speed	S_1, 300 knots	S_2, 500 knots	--	--
Exit Direction	E_1, <250 m, left	E_2, <250 m, right	E_3, 1.5 km, away	E_4, 1.5 km, toward

Note: Table 4 presents the corresponding experimental design.

[a]Slant range of the aircraft from its "target" at breakaway.

are highly correlated with performance, the test will likely show a significant effect for the factor *crew*. The characteristics, to be determined by human factors specialists, could be the results of psychomotor tests, visual search tests, and visual acuity tests.

The factor *time* is included to determine whether guncrews perform better during the second half of the test as a result of the experience gained during the first half of the test. The inclusion of this factor also permits analysis of variance procedures to be applied formally to the first 8 days of experimentation (one-half of the total experiment) with the *time* factor eliminated from the design; this alternative may be taken if some of the gun systems are not operable throughout the complete experiment.

Table 2. FACTORS AND LEVELS--ROTARY-WING AIRCRAFT

Factor	Level 1	Level 2	Level 3	Level 4
Crew	C_1, Crew 1	C_2, Crew 2	--	--
Time	T_1, First half	T_2, Second half	--	--
Tactics	M_1, Popup, Steady	M_2, Popup, Jink	M_3, Moving Fire	M_4, Nap-of-Earth Fly-By
Distance	K_1, 1 km	K_2, 2 km	K_3, 3 km	--
Firing	R_1, Non-firing	R_2, Firing	--	--

Note: Table 5 presents the corresponding experimental design for the firing trials; Table 6 presents a reduced design for the non-firing trials (i.e., the time factor and the distance factor level K_2 do not appear).

The remaining factors in Table 1 describe the flight paths of fixed-wing aircraft. These factors are presumed to affect probability of hit. The particular levels chosen for the design are representative of flight paths used in providing close air support. For example, a 45-degree dive angle and 1.5-km breakaway distance are typical of delivery of unguided bombs, while this same dive angle and 3-km breakaway distance correspond to delivery of guided bombs. A 15-degree dive angle and 1.5-km breakaway distance are representative of strafing or delivery of high-drag bombs, while this same dive angle and 3-km breakaway distance are typical of delivery of short range air-to-surface missiles. Tolerance on dive angle will be $\pm$ 5 degrees; tolerance on breakaway distances will be $\pm$ 300 m.

Breakaway acceleration, which is not a factor in the design, will be from 4 to 5 g's. The *speed* factor is specified at two levels, 300 and 500 knots TAS; the aircraft are to be within

Table 3. FACTORS AND LEVELS--FIXED-WING AIRCRAFT WITH TACTICS

Factor	Level 1	Level 2	Level 3	Level 4
Crew	C_1, Crew 1	C_2, Crew 2		
Tactics	M_1, Straight and Level	M_2, Single Aircraft	M_3, High-Low Pod	M_4, Wagon Wheel
Offset	H_1, <250 m	H_2, 1.5 km		
Firing	R_1, Non-firing	R_2, Firing		

Note: Tables 6 and 7 give the firing and non-firing trials of the design corresponding to these factor levels.

$\pm$ 20 knots of these speeds just before breakaway. The lower speed is typical of AX-type close air support aircraft, while the higher speed corresponds to high performance fighter bombers.

Use of the AX or A-37 at the lower speed and the F-4 at the higher speed will confound speed with aircraft type [1,2] This is not considered a disadvantage because each aircraft is representative of the aircraft that would provide close air support while operating in its particular speed regime.

When fixed-wing aircraft fly as though they are delivering ordnance against targets located away from the guns, the geometrical situation presented to the guns is much different if the aircraft breaks toward the guns than it is if they break away from the guns. To facilitate analysis of the test results, a factor *exit direction* is introduced into the design for Table 1.

[1]That is, the effect of speed and the effect of aircraft type will not be directly distinguishable from each other in the test results.

[2]The Air Force has suggested that one of the prototype AX aircraft may be available for the test.

The distance indicated for the levels of this factor refers to offset, or lateral distance of the "target" of the aircraft from the gun positions. The two values of this distance will result in different time histories of gun angular rates and accelerations. When offset is small (levels E_1 and E_2) the direction of breakaway is likely much less significant than when offset is large (levels E_3 and E_4). Thus, a first order interaction would be expected if offset and direction of breakaway were treated as separate factors.

It is likely that the guncrews will sometimes not see the fixed-wing aircraft until it is too late to deliver fire. While this may be an interesting result, it provides no information about guns *firing* at aircraft. To preclude this occurring too frequently, it is suggested that the test controllers at the guns be continually informed of the range from the guns to the aircraft and that, whenever this range falls below some particular value and the crew of a gun has not detected the aircraft, the controller at that gun should point out the aircraft. All such instances should be identified in the trial records.

All of the trials corresponding to Table 1 involve firing of breakup ammunition, and all use a single aircraft as the target.

Table 2 lists four helicopter tactics. In the two popup maneuvers, the helicopter is initially masked. In *popup steady*, it rises above the mask, hovers for a prescribed period, and descends behind the mask. In *popup jink*, instead of hovering the helicopter moves left and right or up and down or both. The popup tactics represent two methods of delivering missiles. The popup steady tactic could also be used for firing rockets or guns.

The total period of exposure in the popup trials should vary from trial to trial so that the guncrews will not know how much time they have to deliver fire. However, all guns should

fire during a trial; if they do not, it should be repeated. Until the test is started, it will not be known how quickly and consistently the guncrews detect the helicopters. In the absence of this information, the following procedure is recommended: For each trial, randomly select a minimum exposure time. The frequency data of CDCEC test 43.6[1] can be used as a guide. Inform the helicopter pilot and the controller at each gun of this time. Tell the controllers when unmask occurs, and count down the seconds to scheduled remask. Instruct the controllers to point out the helicopter to any guncrew that has not detected it early enough to deliver fire before scheduled remask. The time of alerting the guncrews can be adjusted during the test to ensure that the number of trials that must be repeated is not excessive.

The third tactic is an attack tactic known as "moving fire from forward motion." In this study it will be called simply *moving fire*. In this tactic a helicopter flies nap-of-earth directly toward its target. In the field test the "target" will be the antiaircraft gun area, and the speed of the helicopter will be a safe speed for the terrain, probably 50 to 75 knots. When the helicopter reaches a prescribed range from the guns, it will break away to the left or to the right, turning at the maximum safe acceleration, and will exit the area flying nap-of-earth to take advantage of the local terrain. Attack routes should be selected to control the duration of exposure before breakaway. The moving fire tactic represents one method of delivering TOW and HELLFIRE missiles. Since exposure time after breakaway is not controlled in the test, the tactic is most directly applicable to the launch-and-leave HELLFIRE.

---

[1]"Evaluation of TOW/Helicopter Systems and Antiaircraft Engagement Time," Operational Test and Evaluation of Certain Close Air Support Test Programs, WSEG Report 189 (IDA Study S-403), August 1972, CONFIDENTIAL.

The fourth tactic is *nap-of-earth fly-by*. This is flight on a straight course at altitudes below 5 meters (skid height AGL) and at maximum safe speed. This tactic would be used operationally when traveling near a region that contains enemy antiaircraft guns.

For both the moving fire and nap-of-earth fly-by tactics, a procedure similar to that outlined for the popup tactics should be employed so that all guns are able to fire on most trials.

For the two popup maneuvers, the factor *distance* is the distance of the popup position from the guns. Distances of 2 and 3 km span the ranges for normal use of the TOW antiarmor missile. The developmental HELLFIRE missile could be used at distances greater than 3 km, but greater ranges are of little interest for the purpose of validating models. A distance of 1 km is included so that the effect of distance can be better determined. It does not correspond to doctrine for the employment of attack or observation helicopters.

For the moving fire tactic, *distance* is the distance to breakaway. Here again, 2 and 3 km are in the range of normal use, and 1 km is included to permit the effect of distance to be better determined. For the nap-of-earth fly-by tactic, *distance* is the offset distance (i.e., the minimum horizontal distance from the gun to the helicopter track).

The remaining factor in Table 2, *firing*, has two levels. *Nonfiring* means that the guncrew merely pretends to fire; *firing* means that the guncrew fires breakup ammunition. On any one day of testing, all trials are firing or all are nonfiring. This should simplify logistics as well as ensure that prescribed test conditions will always be met with respect to this factor. The nonfiring level is included here and in Table 3 to permit one to evaluate the importance of firing on the test results. If firing is not important, future testing can presumably be conducted at lower cost with no firing.

An attack helicopter (AH-1 COBRA) should be used for the popup tactics and the moving fire tactic. A light observation helicopter (LOH) is presumed to be operating in support of the AH. The presence of the LOH may affect gun reaction time. This is permissable. However, if any gun fails to bring fire against the AH, the trial must be repeated. A single LOH should be used for the nap-of-earth fly-by tactic.

Table 3 gives the factors and levels for an experiment with fixed-wing aircraft that is directed principally at determining the influence of firing as opposed to merely pretending to fire and the influence of multiple aerial targets on the performance of the guns and guncrews. The factor *tactics* is at four levels. The first two levels employ a single fixed-wing aircraft. Levels 3 and 4 employ a flight of four aircraft.

The level 1 tactic calls for a single aircraft in straight and level flight at 500 knots at an altitude of 500 meters. The speed tolerance is ± 20 knots; altitudes below 500 meters may be used if the selected courses meet applicable safety regulations. This tactic might be used by a "fast FAC" or by a reconnaissance aircraft. Probabilities of hit for this tactic are expected to be much larger than those for the other tactics.

In level 2 a single aircraft performs a 500-knot, 45-degree dive with a 4 to 5-g breakaway initiated 1.5 km from the "target" of the aircraft. For the 1.5 km offset trials breakaway will be away from the guns; for the smaller offset cases breakaway should be to the right for about half the aircraft participating in the trials and should be to the left for the remaining aircraft (the breakaway-right aircraft should be randomly distributed among the breakaway-left aircraft). Tolerances will be ± 20 knots on speed, ± 5 degrees on dive angle, and ± 300 meters on breakaway distance.

In level 3, *high-low pod*, the four aircraft will attack in two elements of two. After approaching at low altitude, the first element will popup and establish a high dive angle (about 45 degrees). The second element will popup and establish a low dive angle (about 15 degrees). Timing will be developed so that the two elements reach the target (from different dive angles and somewhat different azimuths) within a short time but without presenting a safety hazard.

In level 4, *wagon wheel*, the aircraft approach the area of their target in trail but they space their roll-in (turn toward their target) so that they approach their target on different headings.

Each of the aircraft in levels 3 and 4 trials employ the same basic flight path and tolerances as described in level 2 with the exception of those aircraft in the 15 degree dive specified for level 3; except for the 15 degree dive angle, these aircraft also have the same flight path specifications as given for level 2.

Both of these multiaircraft tactics permit several aircraft to attack their target in a short interval of time so that the defenses have little or no opportunity to fire at more than one aircraft. Comparison of levels 3 and 4 with level 2 shows the effect of multiple aircraft relative to single aircraft.

C. THE EXPERIMENTAL DESIGN

Table 4 shows the experimental design corresponding to the factors and levels of Table 1. There are six factors, five at two levels and one at four levels--a total of 128 possible factor combinations. A full replicate of these combinations will be observed with the 128 trials indicated in Table 4. This allows the estimation of all main effects and all two-factor interactions while providing 8 blocks of 16 trials each. A special effort has been made to gain precision by "blocking" the trials into groups in order to control for time of day and daily experience. The 8 blocks of 16 trials translates into 16 days of testing with 8 trials per day, as shown in Table 4. The order of testing on each day is important; the first trials of all 16 days will constitute one block, the second trials a second block, etc.

Note in the first row (heading row) of Table 4 that each crew is scheduled every second day so that experience retention distributions should be similar. The time factor is at the first level for the first eight trial days and at the second level for the last eight trial days; this permits the time (or learning) factor to be analyzed over the complete design or the analysis of variance procedures to be applied formally to the first eight days of experimentation without the time factor. Because the heading row of the table identifies the crew and the time level, the interior lists only the remaining factors.

The design is a modification of Plan 2.7.8 in Fractional Factorial Experiment Designs for Factors at Two Levels, U.S. Department of Commerce, National Bureau of Standards, Applied Mathematics Series Number 48 The basic design, a 1/2 fractional replication of 7 factors in 8 blocks of 8 units each is used for the first eight experiment days, and the other 1/2 fraction is used for the final eight experiment days. The crew labels

Table 4. EXPERIMENTAL DESIGN--FIXED-WING SINGLE AIRCRAFT, FIRING

1	2	3	4	5	6	7	8
C T[a] 1 1	C T 2 1	C T 1 1	C T 2 1	C T 1 1	C T 2 1	C T 1 1	C T 2 1
(1) D B S E 2 2 1 4	(2) D B S E 1 1 2 4	(1) D B S E 1 1 1 1	(2) D B S E 2 2 2 1	(2) D B S E 2 1 2 3	(2) D B S E 1 2 1 3	(1) D B S E 1 2 2 2	(1) D B S E 2 1 1 2
(2) D B S E 2 1 2 1	(3) D B S E 2 1 1 4	(2) D B S E 1 2 2 4	(3) D B S E 1 2 1 1	(3) D B S E 1 1 1 3	(3) D B S E 2 2 2 3	(2) D B S E 2 2 1 2	(3) D B S E 1 1 2 2
(3) D B S E 2 2 2 3	(4) D B S E 2 2 1 2	(4) D B S E 1 1 2 2	(4) D B S E 1 1 1 3	(4) D B S E 2 1 1 4	(4) D B S E 2 1 2 1	(5) D B S E 1 2 1 1	(4) D B S E 1 2 2 4
(4) D B S E 2 1 2 4	(6) D B S E 1 2 1 4	(5) D B S E 1 2 2 1	(6) D B S E 2 1 1 1	(5) D B S E 1 1 1 2	(7) D B S E 2 2 2 2	(7) D B S E 2 2 1 3	(5) D B S E 1 1 2 3
(6) D B S E 2 2 1 1	(7) D B S E 2 2 2 4	(8) D B S E 1 1 1 4	(10) D B S E 1 1 2 1	(9) D B S E 2 1 2 2	(8) D B S E 1 2 1 2	(10) D B S E 1 2 2 3	(6) D B S E 2 1 1 3
(8) D B S E 1 2 1 3	(8) D B S E 1 2 2 2	(11) D B S E 2 1 1 2	(11) D B S E 2 1 2 3	(10) D B S E 1 1 2 4	(10) D B S E 2 2 1 4	(12) D B S E 2 2 2 1	(7) D B S E 1 1 1 1
(13) D B S E 2 2 2 2	(9) D B S E 2 2 1 3	(12) D B S E 1 1 2 3	(12) D B S E 1 1 1 2	(12) D B S E 2 1 1 1	(12) D B S E 1 2 2 1	(13) D B S E 1 2 1 4	(12) D B S E 2 1 2 4
(14) D B S E 1 2 1 2	(10) D B S E 2 1 2 2	(14) D B S E 2 1 1 3	(13) D B S E 1 2 2 3	(14) D B S E 2 2 2 4	(14) D B S E 1 1 1 4	(14) D B S E 1 1 2 1	(13) D B S E 2 2 1 1

Note: Table 1 lists the factor levels and defines the symbols used here. This design is a full replicate consisting of 128 trials; the first 8 and last 8 experiment days each provide a one-half replicate consisting of 64 trials. The numbers in parentheses are sequence numbers for each day. The missing sequence numbers are in Table 5. Trials from Tables 4 and 5 are inter-mixed on each day of testing.

[a]The crew and time levels apply to the entire column.

Table 4. (Continued)

9	10	11	12	13	14	15	16
C T 1 2	C T 2 2	C T 1 2	C T 2 2	C T 1 2	C T 2 2	C T 1 2	C T 2 2
(2) D B S E 2 1 2 3	(1) D B S E 1 2 1 3	(3) D B S E 1 2 2 2	(1) D B S E 2 1 1 2	(2) D B S E 2 2 1 4	(1) D B S E 1 1 2 4	(2) D B S E 1 1 1 1	(1) D B S E 2 2 2 1
(3) D B S E 1 1 1 3	(2) D B S E 1 1 2 2	(5) D B S E 2 2 1 2	(2) D B S E 2 2 2 3	(4) D B S E 2 1 2 1	(3) D B S E 2 1 1 4	(5) D B S E 1 2 2 4	(2) D B S E 1 2 1 1
(5) D B S E 1 2 1 1	(4) D B S E 2 1 2 1	(6) D B S E 2 1 1 4	(5) D B S E 1 2 2 4	(5) D B S E 2 2 2 3	(4) D B S E 1 1 1 3	(7) D B S E 1 1 2 2	(3) D B S E 2 2 1 2
(7) D B S E 1 1 1 2	(6) D B S E 1 1 2 3	(7) D B S E 2 2 1 3	(6) D B S E 2 2 2 2	(9) D B S E 1 2 2 1	(6) D B S E 1 2 1 4	(9) D B S E 2 1 2 4	(5) D B S E 2 1 1 1
(9) D B S E 1 2 2 3	(7) D B S E 1 2 1 2	(10) D B S E 2 1 2 2	(9) D B S E 2 1 1 3	(11) D B S E 1 1 1 4	(B) D B S E 1 1 2 1	(11) D B S E 2 2 1 1	(6) D B S E 2 2 2 4
(11) D B S E 1 1 2 4	(8) D B S E 1 1 1 1	(11) D B S E 2 2 2 1	(10) D B S E 2 2 1 4	(12) D B S E 2 1 1 2	(9) D B S E 1 2 2 2	(12) D B S E 1 2 1 3	(12) D B S E 2 1 2 3
(13) D B S E 1 2 1 4	(9) D B S E 2 1 2 4	(12) D B S E 2 1 1 1	(13) D B S E 1 2 2 1	(13) D B S E 2 2 2 2	(12) D B S E 1 1 1 2	(13) D B S E 1 1 2 3	(13) D B S E 2 2 1 3
(14) D B S E 2 2 2 4	(11) D B S E 2 2 1 1	(14) D B S E 1 1 2 1	(14) D B S E 1 1 1 4	(14) D B S E 2 1 1 3	(14) D B S E 1 2 2 3	(14) D B S E 1 2 1 2	(14) D B S E 2 1 2 2

and the block order have been randomized; the factor labels have been effectively randomized--they were assigned alphabetical labels to aid in their identification (e.g., C for crew). All two factor interactions are not confounded with blocks.

Table 5 presents the firing part of the experimental design that corresponds to Table 2. These rotary-wing trials are arranged in 16 columns of 6 trials each. The columns are intended to correspond to the same days as the columns of Table 4. It is assumed that the eight trials in a column of Table 4 and the six trials of the corresponding column of Table 5 can all be conducted on the same day.

As with the design shown in Table 4, the experimental design presented in Table 5 can be altered so as to permit analysis of variance procedures to be applied formally to the data from just the first eight days of experimentation (one-half of the total experiment) with the time factor omitted.

The order of the fixed-wing trials and the order of the rotary-wing trials should be maintained,[1] but the rotary-wing trials should be interspersed at random among the fixed-wing trials so that guncrews do not know which type aircraft they will encounter next. The numbers in parentheses in Tables 4 and 5 are sequence numbers that provide an appropriate ordering of trials for each day of testing. The order of testing on each day as specified in Tables 4 and 5 may be changed shortly before the test starting date. This would be done in order to reduce the likelihood of the gun crews learning too much information beforehand about the expected test aircraft attack and thus making the test less realistic.

---

[1]This will preserve much of the blocking of the fixed-wing trials and will retain the randomization of the rotary-wing trials.

Table 5. EXPERIMENTAL DESIGN--ROTARY-WING AIRCRAFT, FIRING

1	2	3	4	5	6	7	8
C_1 T_1	C_2 T_1	C_1 T_1	C_2 T_1	C_1 T_1	C_2 T_1	C_1 T_1	C_2 T_1
(5) M_1 K_3	(1) M_2 K_1	(3) M_2 K_3	(1) M_4 K_1	(1) M_1 K_1	(1) M_1 K_3	(3) M_4 K_2	(2) M_4 K_2
(7) M_2 K_1	(5) M_2 K_2	(6) M_4 K_3	(5) M_3 K_2	(6) M_2 K_2	(5) M_3 K_1	(4) M_3 K_1	(8) M_4 K_3
(9) M_4 K_1	(11) M_1 K_1	(7) M_1 K_2	(7) M_2 K_3	(7) M_3 K_2	(6) M_1 K_2	(6) M_3 K_3	(9) M_3 K_3
(10) M_3 K_2	(12) M_4 K_3	(9) M_3 K_1	(8) M_1 K_1	(8) M_2 K_1	(9) M_4 K_1	(8) M_2 K_3	(10) M_1 K_2
(11) M_4 K_2	(13) M_1 K_3	(10) M_2 K_2	(9) M_3 K_3	(11) M_1 K_3	(11) M_4 K_2	(9) M_1 K_1	(11) M_2 K_1
(12) M_3 K_3	(14) M_3 K_2	(13) M_4 K_1	(14) M_2 K_2	(13) M_4 K_3	(13) M_2 K_3	(11) M_1 K_2	(14) M_3 K_1

9	10	11	12	13	14	15	16
C_1 T_2	C_2 T_2	C_1 T_2	C_2 T_2	C_1 T_2	C_2 T_2	C_1 T_2	C_2 T_2
(1) M_3 K_1	(3) M_3 K_3	(1) M_3 K_3	(3) M_4 K_2	(1) M_1 K_1	(2) M_3 K_2	(1) M_2 K_2	(4) M_2 K_1
(4) M_4 K_3	(5) M_2 K_2	(2) M_3 K_2	(4) M_1 K_3	(3) M_2 K_1	(5) M_4 K_1	(3) M_1 K_2	(7) M_4 K_3
(6) M_1 K_3	(10) M_2 K_3	(4) M_4 K_1	(7) M_1 K_2	(6) M_4 K_2	(7) M_1 K_1	(4) M_2 K_3	(8) M_3 K_1
(8) M_1 K_2	(12) M_3 K_1	(8) M_2 K_2	(8) M_3 K_3	(7) M_3 K_3	(10) M_3 K_2	(6) M_3 K_1	(9) M_4 K_3
(10) M_3 K_2	(13) M_4 K_2	(9) M_1 K_1	(11) M_2 K_1	(8) M_1 K_3	(11) M_2 K_3	(8) M_4 K_3	(10) M_1 K_2
(12) M_2 K_1	(14) M_1 K_1	(13) M_2 K_3	(12) M_4 K_1	(10) M_4 K_2	(13) M_1 K_3	(10) M_4 K_1	(11) M_2 K_2

Note: Table 2 lists the factor levels and defines the symbols used here. This design is two full replicates consisting of 96 trials; the first 8 and last 8 experiment days each provide two full replicates consisting of 48 trials without the learning time factor. The numbers in parentheses are sequence numbers (see Table 4).

The nonfiring part of the experimental design corresponding to Table 2 is shown in the lower part of Table 6. These rotary-wing trials comprise four full replicates of a reduced design (i.e., the time factor and the second level of distance, K_2, do not appear). There are 64 trials grouped into 8 columns of 8 trials each. The columns are intended to correspond to days of testing. The rotary-wing trials in Tables 5 and 6 have not been blocked. Instead they have been randomized separately on each day.

The nonfiring portion of the design for Table 3 is given in the upper part of Table 6. The fixed-wing trials and rotary-wing trials in each column of Table 6 should be conducted on the same day. The order of fixed- and rotary-wing trials in any day should be maintained, but the fixed- and rotary-wing trials should be interspersed in a random fashion. The sequence numbers in Table 6 provide such a random ordering of trials.

The firing portion of the design for Table 3 will be performed on four additional days, as described in Table 7. These days can also be used to make up missed or invalid firing trials for the experiment described in Tables 4 and 5. Care should be taken to schedule these makeup trials so that they occur in approximately the same daily position as called for in the original schedule. Thus, they should be inserted first, and the trials described in Table 7 should be scheduled around them. Note that the Table 7 trials have not been blocked. It is assumed that the complexity of the factor *tactics* will diminish the daily learning factor, and they have been suitably randomized.

Table 6. EXPERIMENTAL DESIGN--FIXED- AND ROTARY-WING AIRCRAFT, NONFIRING

1	2	3	4	5	6	7	8
C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2
FIXED-WING							
(2) $M_4\ H_2$	(2) $M_4\ H_2$	(1) $M_2\ H_2$	(1) $M_1\ H_2$	(1) $M_2\ H_1$	(1) $M_2\ H_1$	(3) $M_3\ H_1$	(1) $M_3\ H_2$
(4) $M_2\ H_1$	(3) $M_4\ H_1$	(3) $M_3\ H_2$	(2) $M_3\ H_1$	(2) $M_4\ H_2$	(2) $M_2\ H_2$	(4) $M_1\ H_1$	(2) $M_4\ H_1$
(5) $M_1\ H_2$	(6) $M_2\ H_2$	(5) $M_4\ H_1$	(5) $M_1\ H_1$	(3) $M_1\ H_2$	(3) $M_3\ H_1$	(6) $M_4\ H_1$	(3) $M_4\ H_2$
(6) $M_1\ H_1$	(7) $M_2\ H_1$	(7) $M_3\ H_1$	(8) $M_3\ H_2$	(7) $M_3\ H_2$	(4) $M_1\ H_1$	(7) $M_2\ H_2$	(7) $M_1\ H_2$
(7) $M_4\ H_1$	(8) $M_3\ H_1$	(9) $M_4\ H_2$	(9) $M_4\ H_1$	(9) $M_4\ H_1$	(7) $M_1\ H_2$	(11) $M_4\ H_2$	(8) $M_2\ H_1$
(8) $M_3\ H_2$	(9) $M_3\ H_2$	(10) $M_1\ H_2$	(11) $M_4\ H_2$	(12) $M_3\ H_1$	(8) $M_4\ H_2$	(12) $M_2\ H_1$	(11) $M_1\ H_1$
(9) $M_2\ H_2$	(11) $M_1\ H_1$	(13) $M_2\ H_1$	(13) $M_2\ H_1$	(14) $M_2\ H_2$	(9) $M_4\ H_1$	(13) $M_3\ H_2$	(15) $M_2\ H_2$
(11) $M_3\ H_1$	(14) $M_1\ H_2$	(15) $M_1\ H_1$	(16) $M_2\ H_2$	(16) $M_1\ H_1$	(10) $M_3\ H_2$	(14) $M_1\ H_2$	(16) $M_3\ H_1$
ROTARY-WING							
(1) $M_3\ K_3$	(1) $M_1\ K_3$	(2) $M_2\ K_1$	(3) $M_4\ K_3$	(4) $M_2\ K_1$	(5) $M_3\ K_3$	(1) $M_4\ K_3$	(4) $M_1\ K_3$
(3) $M_4\ K_3$	(4) $M_3\ K_1$	(4) $M_2\ K_3$	(4) $M_2\ K_1$	(5) $M_1\ K_1$	(6) $M_4\ K_1$	(2) $M_4\ K_1$	(5) $M_2\ K_3$
(10) $M_1\ K_3$	(5) $M_3\ K_3$	(6) $M_3\ K_1$	(6) $M_2\ K_3$	(6) $M_2\ K_3$	(11) $M_2\ K_1$	(5) $M_3\ K_1$	(6) $M_4\ K_3$
(12) $M_4\ K_1$	(10) $M_4\ K_1$	(8) $M_1\ K_1$	(7) $M_1\ K_1$	(8) $M_3\ K_3$	(12) $M_3\ K_1$	(8) $M_1\ K_3$	(9) $M_1\ K_1$
(13) $M_1\ K_1$	(12) $M_2\ K_3$	(11) $M_4\ K_1$	(10) $M_3\ K_3$	(10) $M_4\ K_3$	(13) $M_2\ K_3$	(9) $M_1\ K_1$	(10) $M_4\ K_1$
(14) $M_2\ K_3$	(13) $M_2\ K_1$	(12) $M_4\ K_3$	(12) $M_4\ K_1$	(11) $M_3\ K_1$	(14) $M_1\ K_3$	(10) $M_3\ K_3$	(12) $M_3\ K_3$
(15) $M_2\ K_1$	(15) $M_1\ K_1$	(14) $M_3\ K_3$	(14) $M_1\ K_3$	(13) $M_4\ K_1$	(15) $M_4\ K_3$	(15) $M_2\ K_3$	(13) $M_3\ K_1$
(16) $M_3\ K_1$	(16) $M_4\ K_3$	(16) $M_1\ K_3$	(15) $M_3\ K_1$	(15) $M_1\ K_3$	(16) $M_1\ K_1$	(16) $M_2\ K_1$	(14) $M_2\ K_1$

Notes: The fixed-wing trials are the non-firing part of the design corresponding to the factor levels in Table 3. These 64 trials provide four trials for each set of non-firing conditions in Table 3. The 64 trials of Table 6 plus the 32 firing trials of Table 7 provide two full replicates (each composed of 32 trials) corresponding to Table 3 plus an additional 32 non-firing trials.

The rotary-wing trials are the non-firing part of the design corresponding to the factor levels in Table 2. These 64 non-firing trials are four full replicates (each consisting of 16 trials) with the time factor and the distance factor level K_2 not in the design.

Table 7. EXPERIMENTAL DESIGN--FIXED-WING AIRCRAFT, FIRING

1	2	3	4
C_1	C_2	C_1	C_2
M_3 H_1	M_4 H_1	M_4 H_2	M_4 H_2
M_1 H_1	M_2 H_2	M_1 H_2	M_2 H_1
M_3 H_2	M_1 H_1	M_2 H_1	M_3 H_2
M_4 H_1	M_1 H_2	M_2 H_2	M_3 H_1
M_1 H_2	M_3 H_2	M_3 H_1	M_4 H_1
M_2 H_1	M_4 H_2	M_3 H_2	M_1 H_1
M_2 H_2	M_2 H_1	M_1 H_1	M_1 H_2
M_4 H_2	M_3 H_1	M_4 H_1	M_2 H_2

Note: These trials are the firing part of the design corresponding to Table 3. These 32 firing trials are two full replicates (each consisting of 16 trials). See Table 6.